

Very Large Computer Generated Holograms for Measuring Aspheric Optical Surfaces

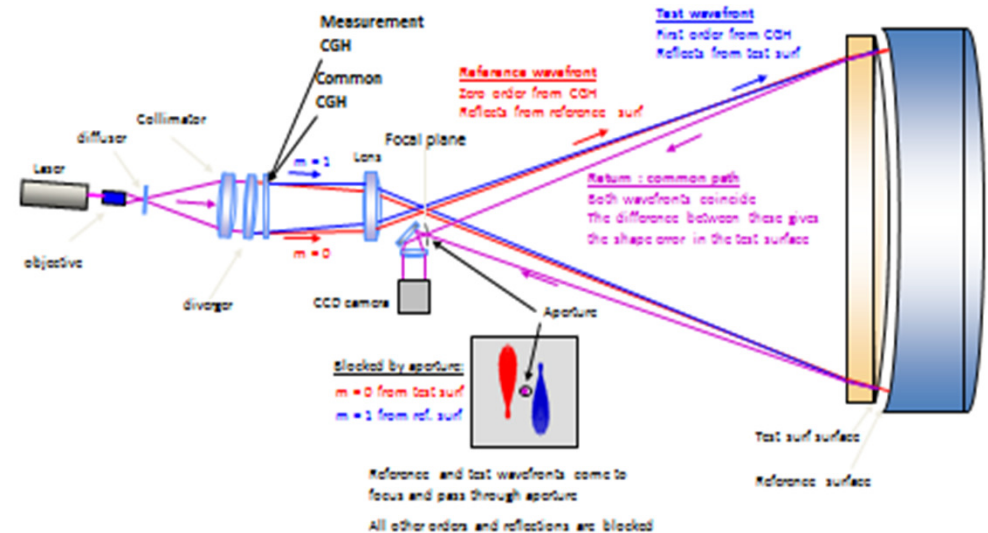
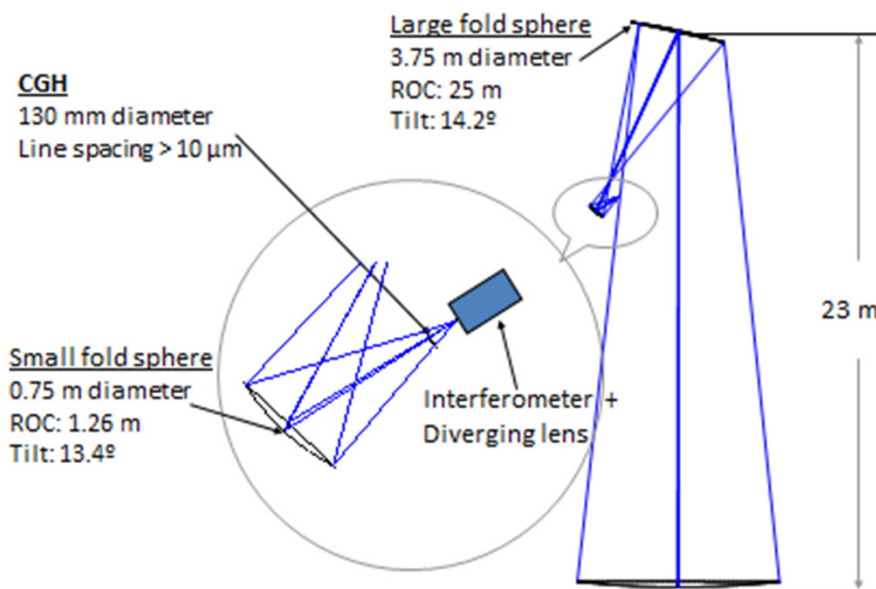
Chunyu Zhao

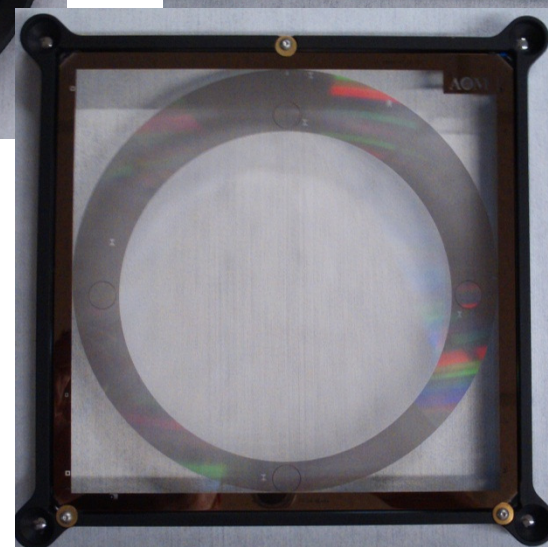
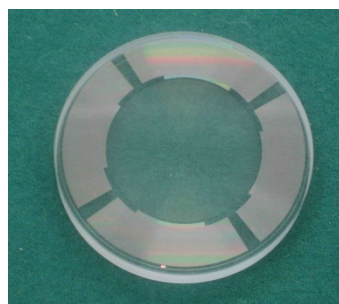
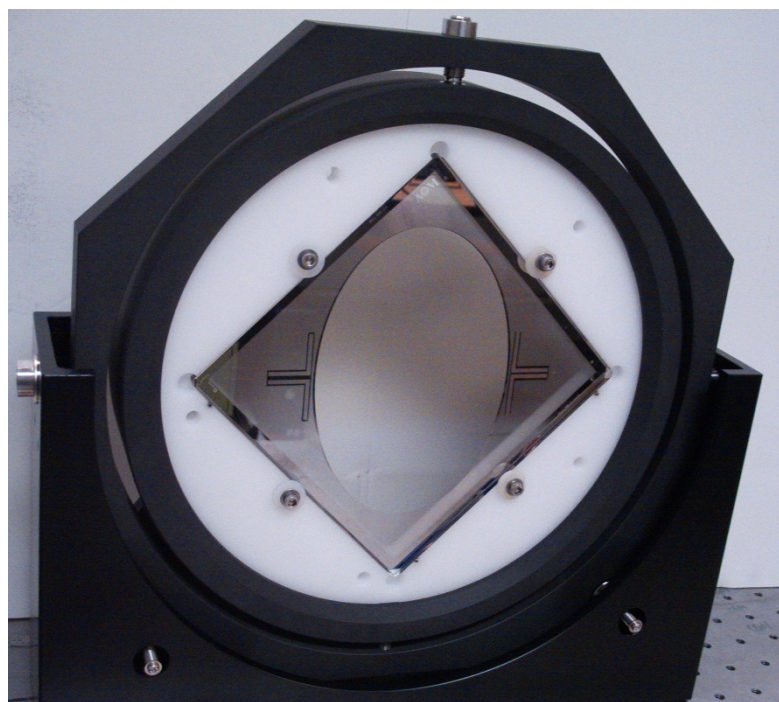
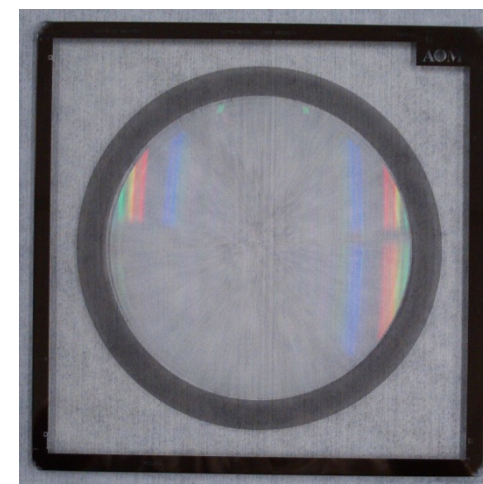
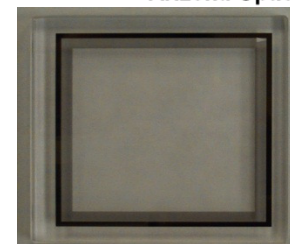
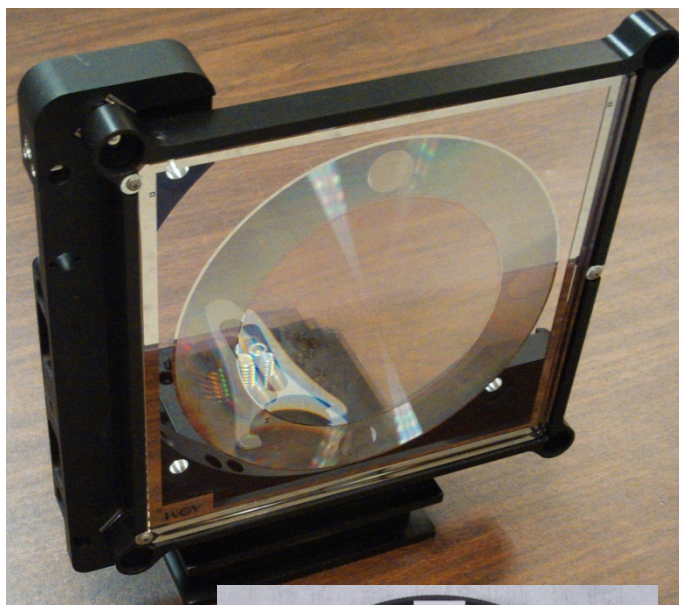
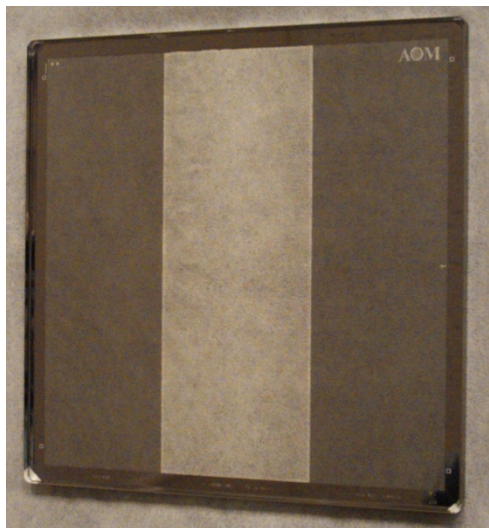
Arizona Optical Metrology LLC

Outline

- Brief history of AOM
- Preliminary results of large CGH development effort funded by NASA SBIR Contract NNX12CF50P

- **Arizona Optical Metrology LLC** was founded in 2009 by Jim Burge and Chunyu Zhao
- www.cgnulls.com
- We provide Computer Generated Holograms and general optical metrology services

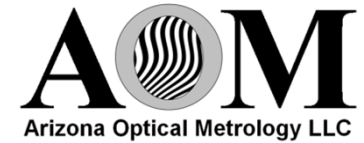




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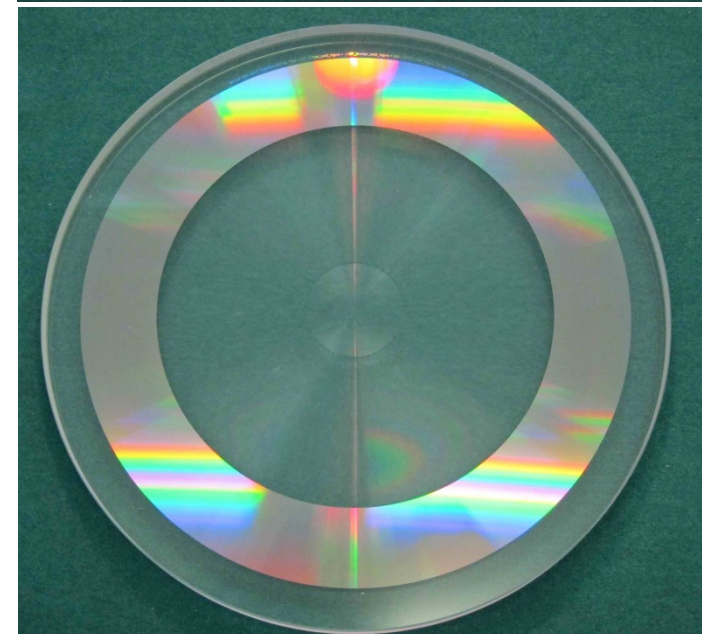
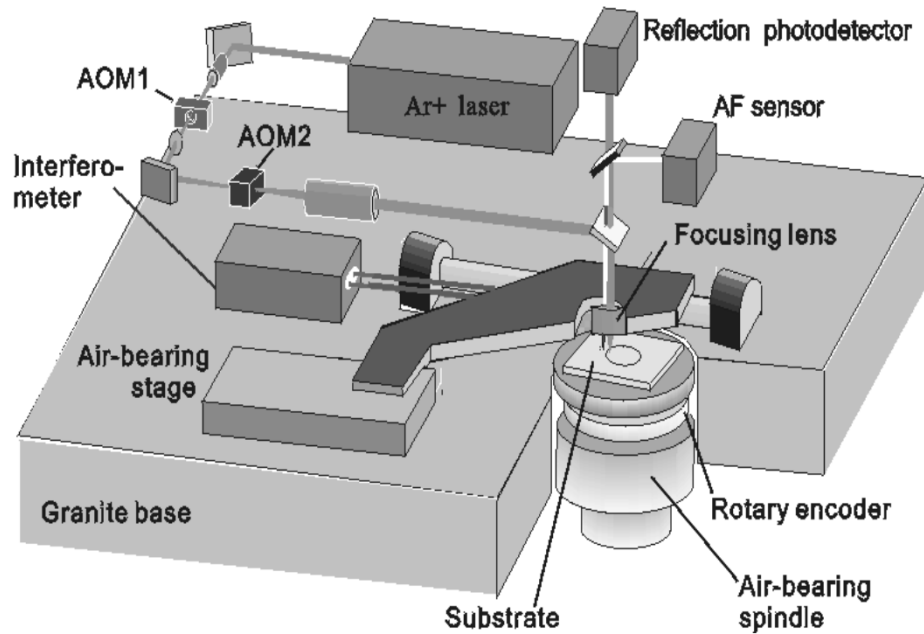
Mirror Tech Days 2012

Advantage of Large CGH



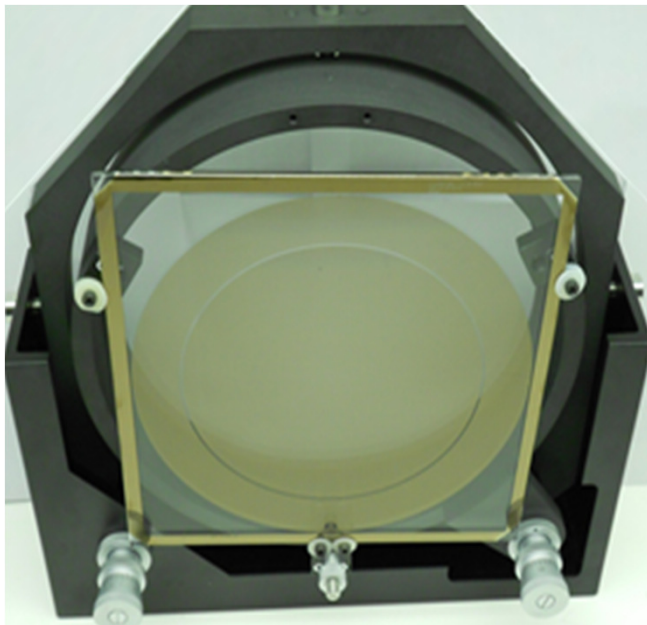
- What is “large”?
 - 9” round or square
- Performance-wise, larger is always better
 - Less distortion
 - Better imaging
- **But it is hard to get!**

Circular Laser Writer



Can write accurately on good quality custom substrates up to 9" diameter, but limited to only **CIRCULAR** patterns!

9" square CGH

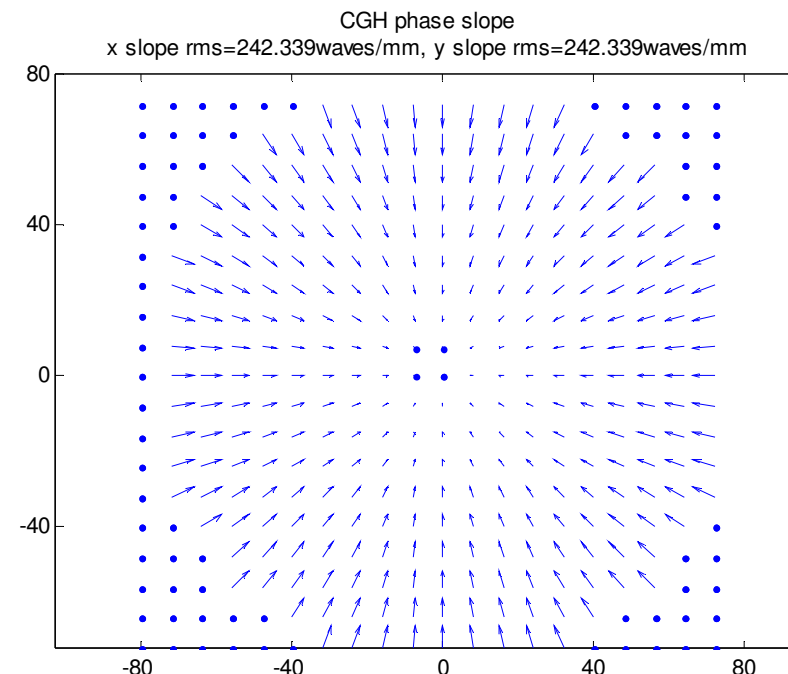
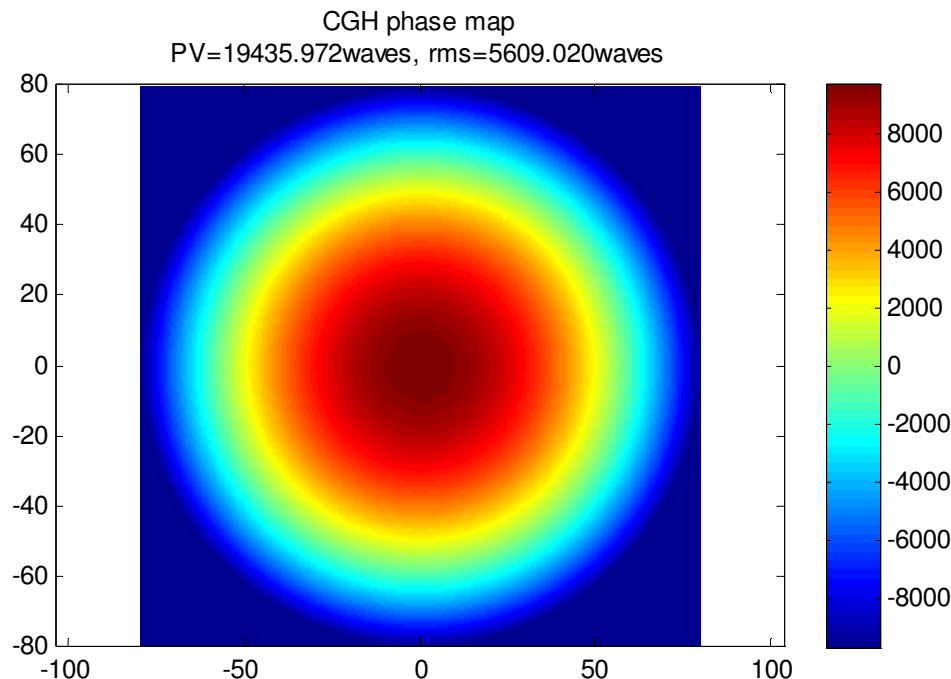


- Pattern is general – does not have to be circular
- Only **0.12"** thick
- Writing accuracy is **not** great

What we want is general patterns written accurately on large, thick and high quality substrate!

- Our collaboration partner at JPL developed capabilities to write **general patterns** on **high quality** fused silica substrate of **9" diameter** and **12mm thickness** with their JEOL e-beam machine.
- But the **writing accuracy** is **not** great.
- But if we can measure the writing error accurately, we can predict the wavefront error due to writing and back it out from aspheric surface measurement.

Writing error to wavefront error



$$\Delta W(x, y) = m \cdot \vec{\epsilon}(x, y) \cdot \vec{S}(x, y)$$

ΔW is **wavefront error**,

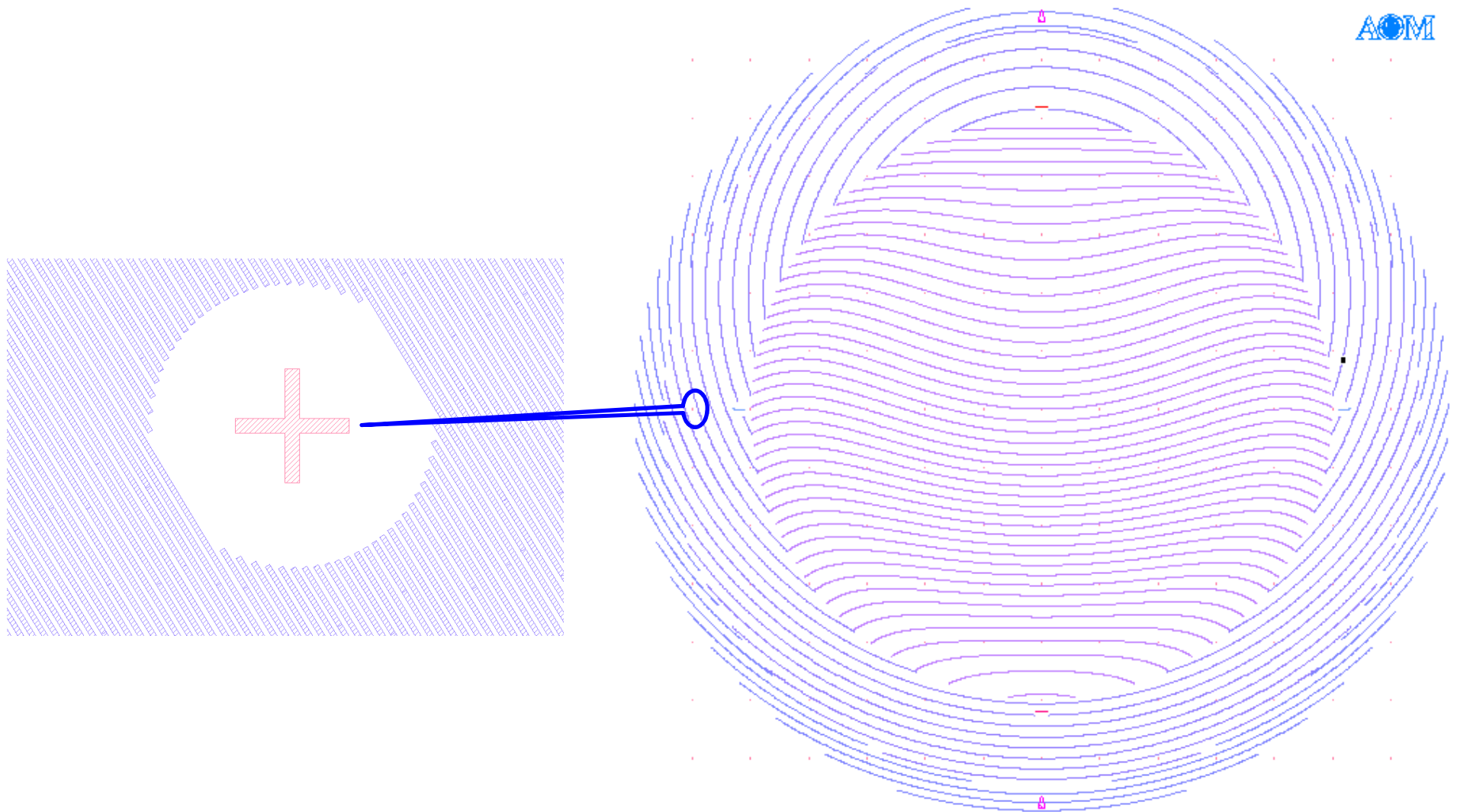
m is diffraction order,

$\vec{\epsilon}$ is the local **writing error**, and

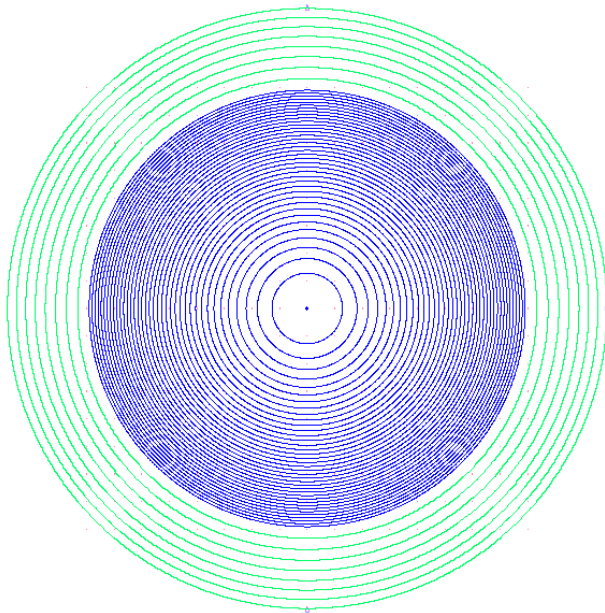
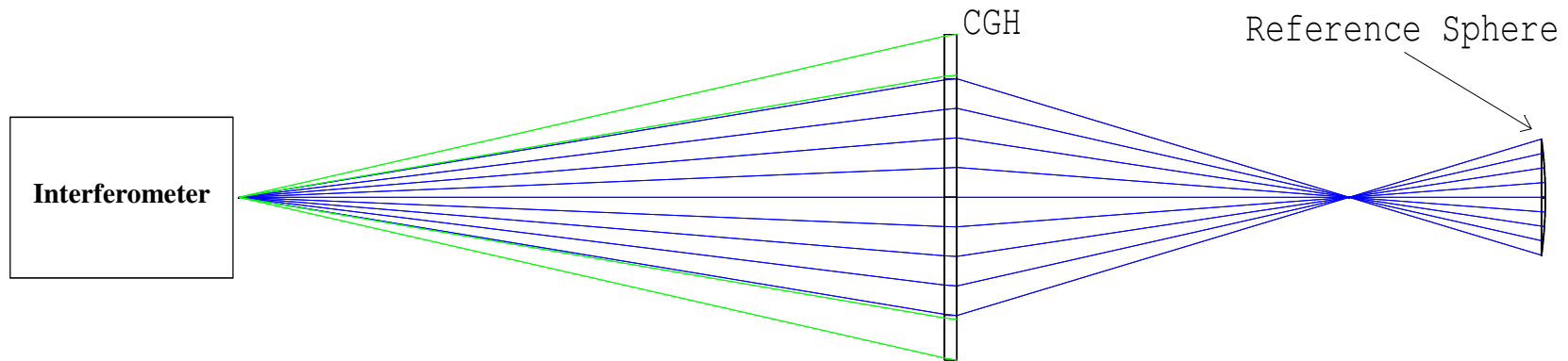
\vec{S} is the local **phase slope**.

$$\vec{S}(x, y) = -\nabla \Phi(x, y).$$

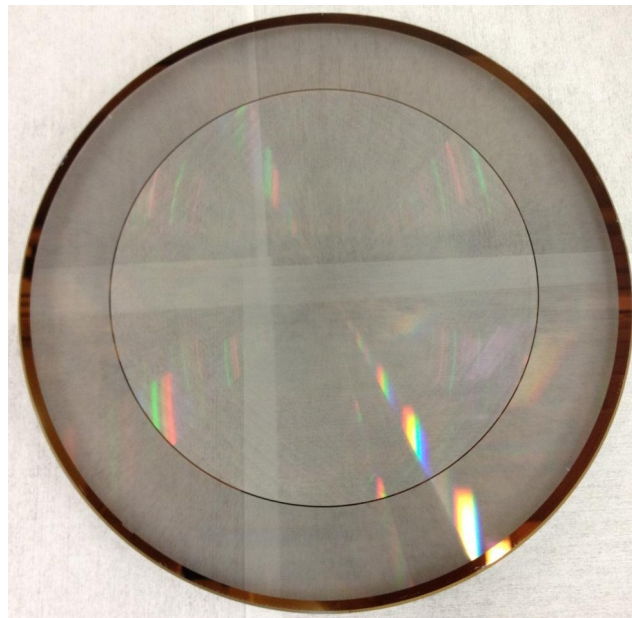
Cross hairs embedded in CGH patterns



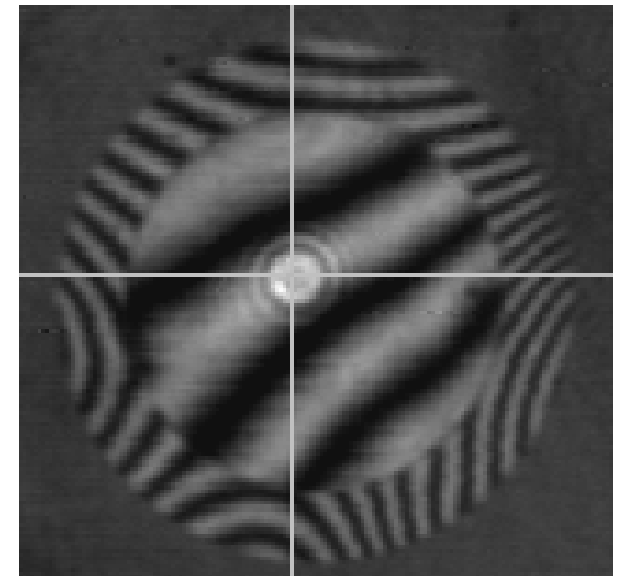
Sample CGH Design, Fabrication and testing



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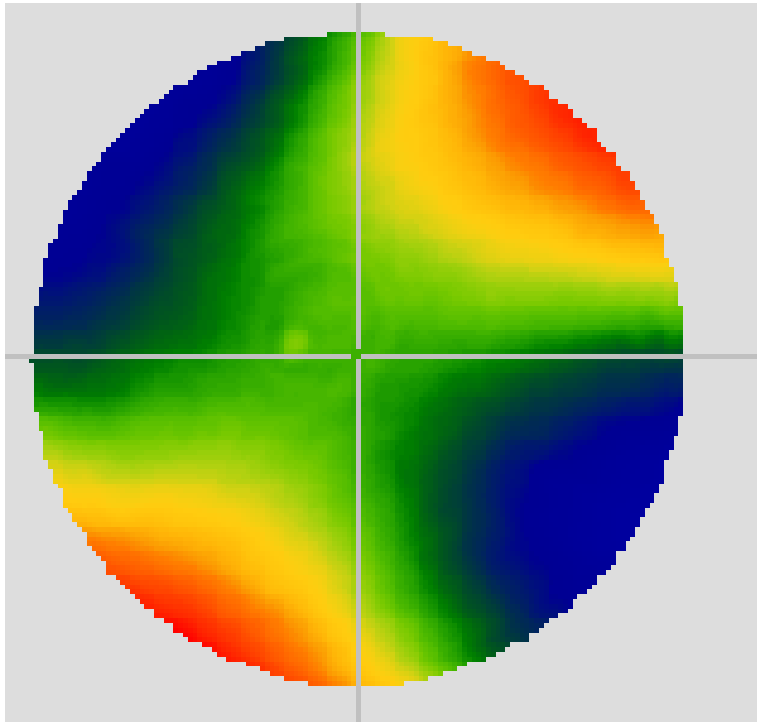


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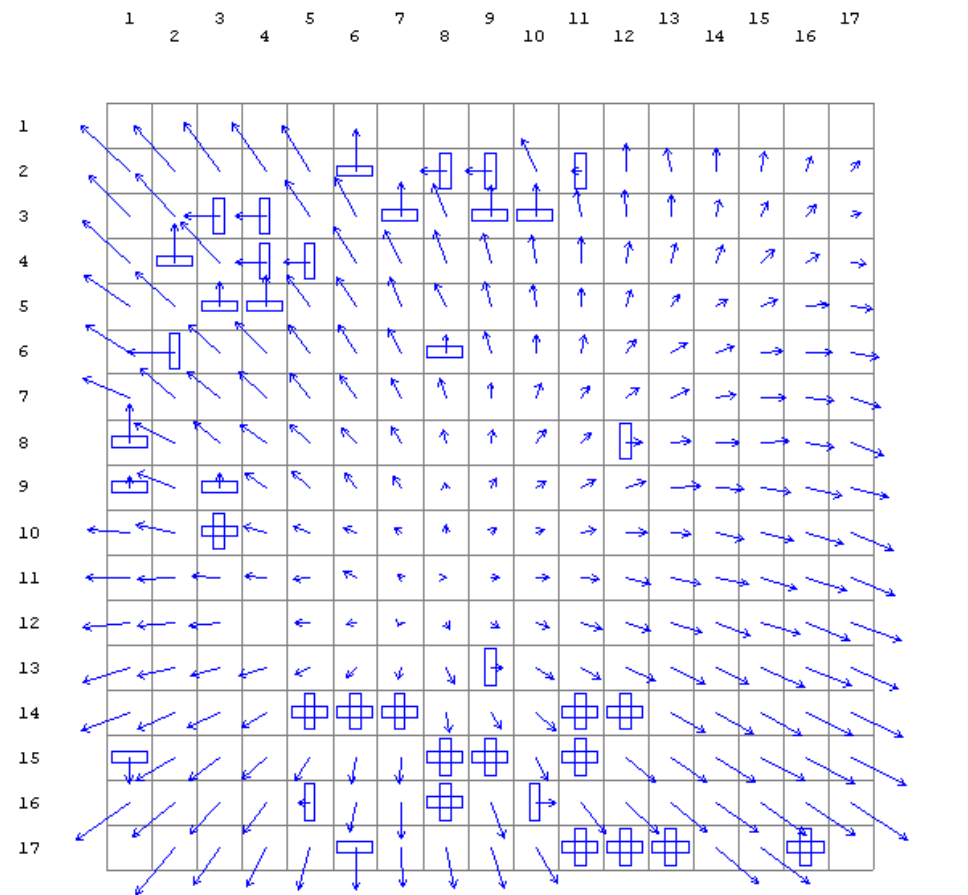
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Wavefront error



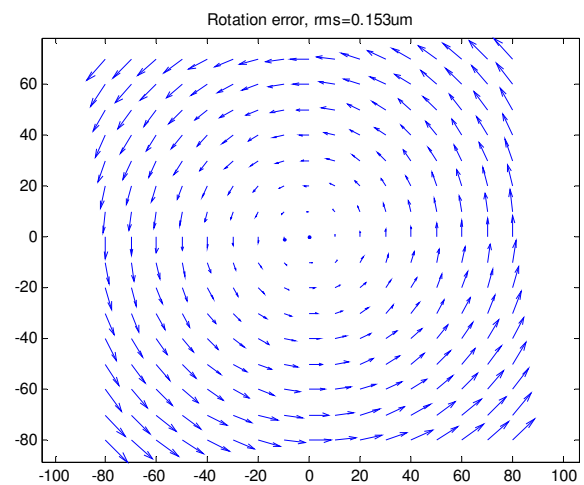
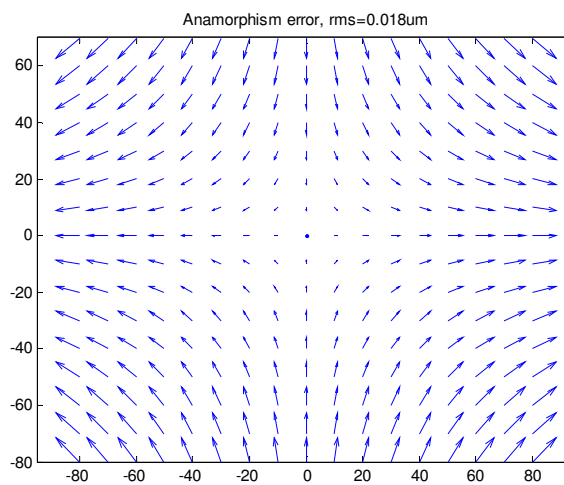
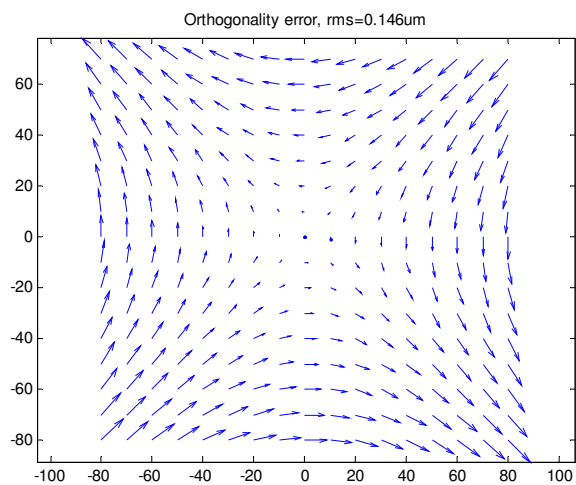
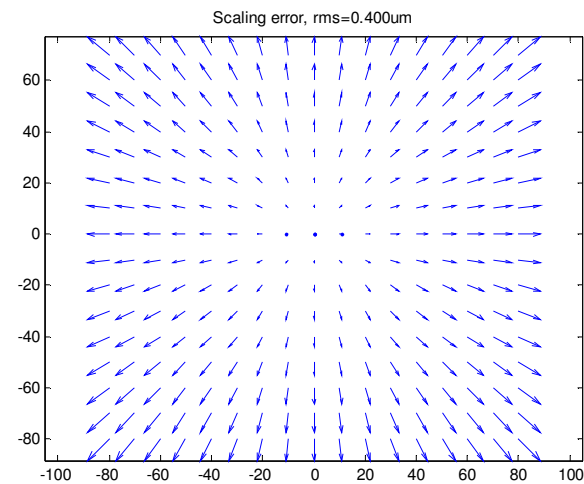
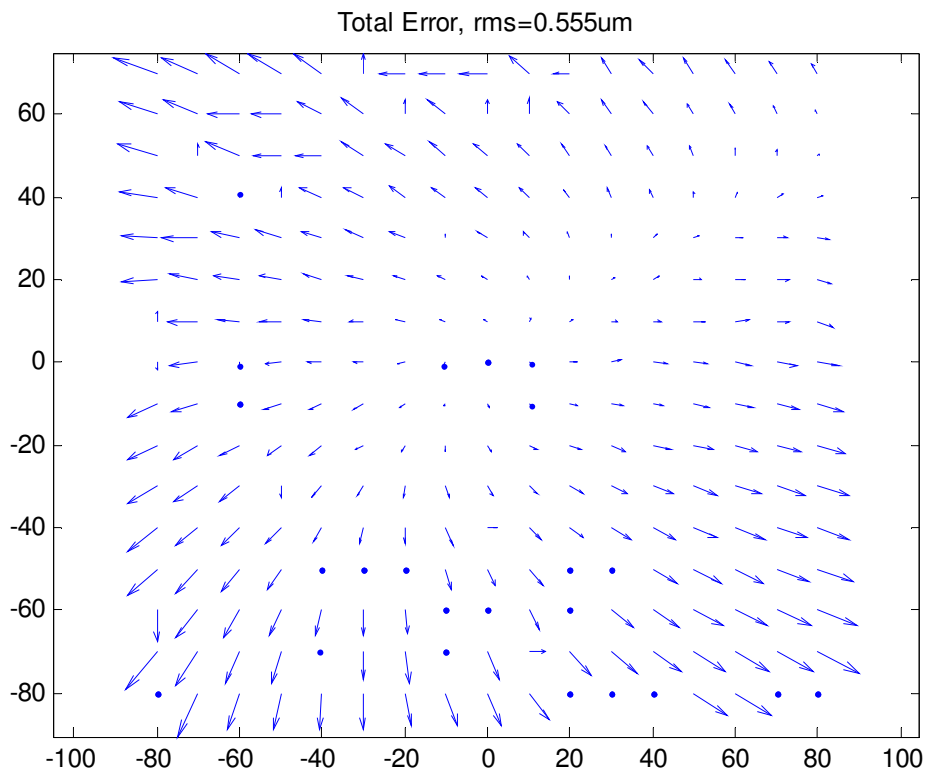
- Calibrated the Transmission Sphere, TWE of the CGH substrate.
- Measurements were made at 4 reference sphere's clocking angles - 0° , 90° , 180° and 270° to average out possible 1θ and 2θ errors in the reference sphere.
- Wavefront error for the CGH writing error:
 - PV: 0.27λ , rms: 0.061λ nm
 - **Astigmatism: 0.059λ rms**
 - After removing 15 Zernike terms, residual rms 3.0nm
 - After removing 35 Zernike terms, residual rms 1.5nm

Registration Measurement

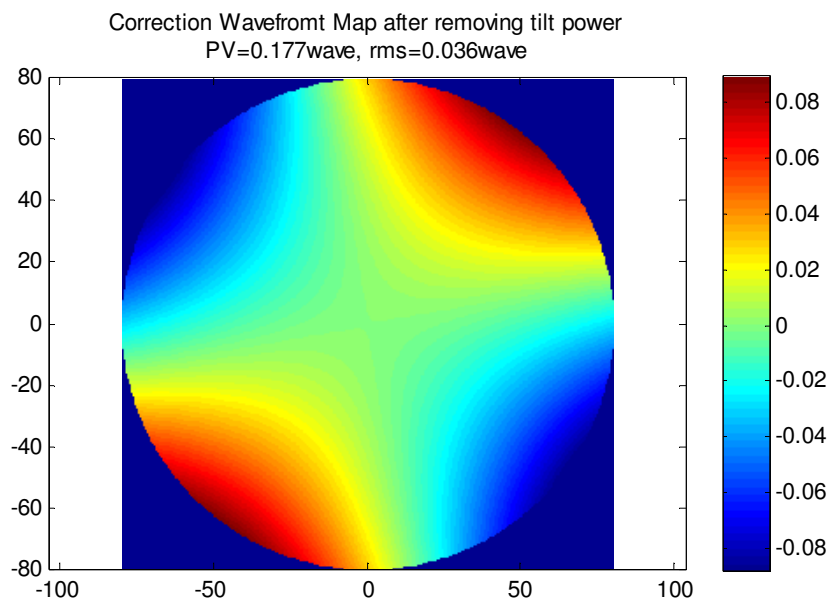


<u>Scales [ppm]</u>	<u>Orthogonality [10⁻⁶ rad]</u>	<u>Processing</u>
1 : 7.805 / 6.967	1 : -4.093 // 1.732 / -2.360	Sites : SELECTED
		⊞ Missed Measurements
		Alignment : ALL
		- f.: Design data
Summary	X [nm]	Y [nm]
Mean	13.97	29.26
Max 3 S.D.	1258.70	1032.42
Min	-842.86	-732.63
Max	870.69	763.51

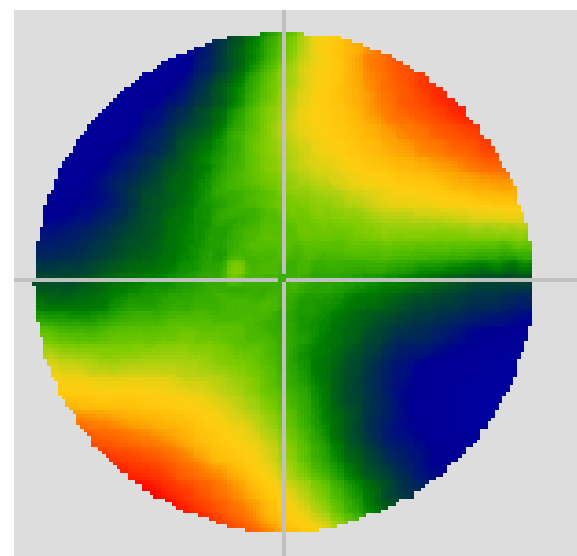
1 : F:\Output\A-OPTICAL\PO12015.NBC
ARIZONA OPTICAL
10:45AM, Wednesday, June 20, 20



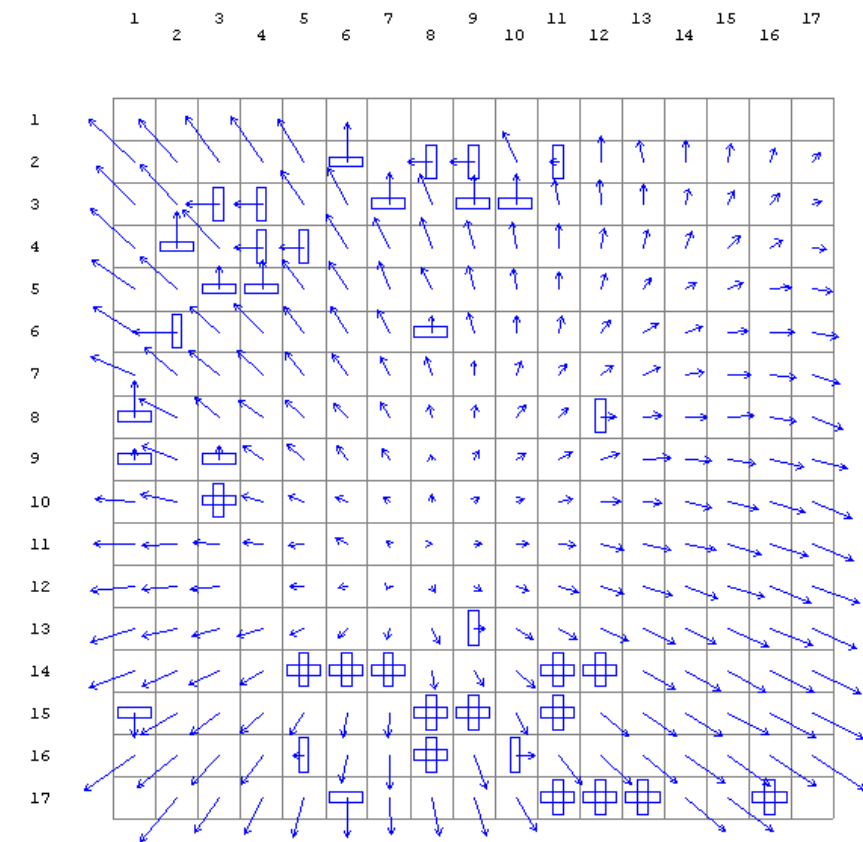
Theory vs. measurement



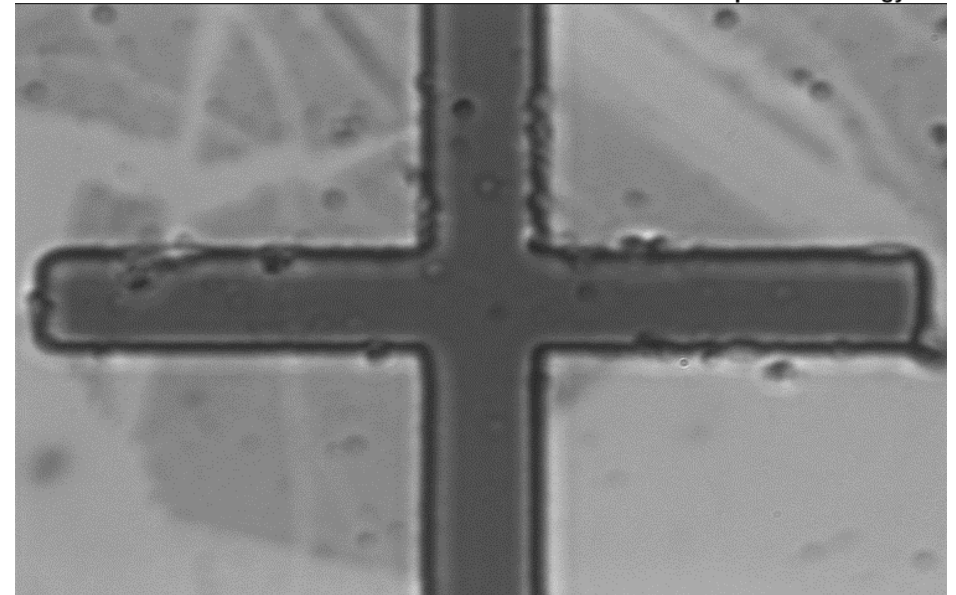
PV: 0.18, rms: 0.036 λ nm
Astigmatism: 0.036 λ rms



PV: 0.27 λ , rms: 0.061 λ nm
Astigmatism: 0.059 λ rms



Scales [ppm]	Orthogonality [10^{-6} rad]		Processing
1 : 7.805 / 6.967	1 : -4.093 // 1.732 / -2.360		Sites : SELECTED
			= [Missed Measurements
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Summary	X [nm]	Y [nm]	1 : F:\Output\A-OPTICAL\PO12015.NB0
Mean	13.97	29.26	ARIZONA OPTICAL
Max 3 S.D.	1258.70	1032.42	10:45AM, Wednesday, June 20, 20
Min	-842.86	-732.63	
Max	870.69	763.51	



To be done

- Understand the registration measurement better. Figure out if it has systematic error due to the large CGH
- Improve the writing quality such that the cross hairs are clean and their positions can be measured more accurately